Using the Royal Building System in Theater Construction

By Captain Samuel Pickands

This article describes the Royal Building System (RBS) as used in the New Horizons 2002 exercises in Nicaragua and El Salvador. The intent of the article is not to summarize the New Horizons 2002 projects or evaluate exercise results but to present to the military engineering community lessons learned from using the RBS. This system is one of several similar construction systems available today.

As part of the Deputy Joint Chiefs of Staff-directed New Horizons exercise organized by the U.S. Southern Command, active duty and reserve engineers from all four services train by building public infrastructure and utilities throughout Central and South America. The arrangement has been ideal for creating and maintaining expertise in theater construction methods in U.S. Army engineering units, while providing needed infrastructure projects to our American neighbors.

New Horizons 2002 did not focus engineer training on the concrete masonry building materials typically used in theater construction. Instead, U.S. Army South (USARSO) elected to use the Canadian-developed RBS for vertical construction. In the Caribbean, civilian RBS buildings have withstood tropical storms that leveled their conventional neighbors, bolstering the vendor's claims that the resulting buildings are among the most survivable structures, even though they can be built relatively quickly.

The RBS uses vinyl wall forms constructed of 4-, 6-, or 8-inch-wide modular sections to create a single continuous "mold" of a building. Vertical steel reinforcing bars are fixed into an underlying concrete slab and interweave through this mold, and they are tied together by horizontal steel bars. Finally, concrete is poured into the formwork from above in "lifts" or layers. Once the concrete sets, the result is a reinforced-concrete building with a colored vinyl covering.

The potential uses of these rapidly built reinforced-concrete buildings are obvious. Buildings that can be built quickly yet are well insulated, relatively soundproof, and resistant to blast damage, fires, and small-arms fire have many applications in semipermanent forward installations.

Designs for the project buildings were supplied to the task force by USARSO, and the vendor used the designs to project a bill of materials (BOM) for each site and supply the correct components. U.S. Army reservists from the 389th Engineer Battalion (Iowa), Marine reservists from the 6th Engineer Support Battalion, and active duty sailors from the 4th Naval Mobile Construction Battalion (Seabees) were all assigned RBS projects. None of the units had prior experience with the system, and both Marine and Army construction crews rotated out every two weeks, leaving only a handful of cadre for the duration of the exercise.

The New Horizons environment in Central America was ideal for testing the RBS. The tropical heat and limited infrastructure of the host nations mirrored the challenging

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **MAR 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE **Using the Royal Building System in Theater Construction**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army Engineer School,14010 MSCoE Loop BLDG 3201, Suite 2661,Fort Leonard Wood ,MO,65473-8702**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

conditions in forward-deployed operations. The reinforced-concrete buildings produced are also sure to be appreciated in the region where earthquakes and extreme weather are the norm.

In general, RBS wall forms were simple to use and suitable for military construction, even with untrained crews. Like any system, however, many lessons were learned from the first use of the RBS. If your unit has an opportunity to build with the RBS, you will profit by incorporating these lessons learned during your training, engineering, and logistics planning.

Assembly and Training

Building walls with the RBS is theoretically much faster than building with concrete masonry units (CMUs). Under ideal conditions (expert crews familiar with the RBS, good weather, horizontal work complete, all equipment and parts available, and long workdays) RBS structures can be built in 72 hours. These examples, however, are not useful for military planning, since they fail to account for the military realities of personnel rotation, confusion of site BOMs in shipment, remote worksites, BOM shortages, formwork adaptations to extreme climates, heat category work-rate limitations, time lost to force protection measures, local vendor delays, and utility connection delays.

When planning, leaders must also remember that the RBS is primarily a wall system. With trained leadership, wall construction may be faster with the RBS, but horizontal work and slab preparation are virtually identical to CMU construction. Roofing, utilities, doors and windows, and internal finishing are somewhat faster with the RBS, but at least initially, even these advantages will be offset by the unfamiliarity of the system. If your unit is not experienced at horizontal, utilities, roofing, and finishing work, your worksite progress will be slow, whether or not you use the RBS correctly.

In the final analysis, *RBS wall construction is not faster than CMU construction unless and until the worksite leadership has experience with the system.* Fortunately, the learning curve with the RBS is very steep, and a small number of trained cadre can shorten construction time even with untrained crews. For example, Task Force Oxelotlan needed 10 days to install the wall forms and pour the concrete at its first project, the San Marcos Lempas School in El Salvador. However, after the cadre had become familiar with the RBS, the task force was able to use two trained NCOs and an untrained multinational construction crew to install rebar forms and pour the walls in just 6 days for the Zamoran School. An even steeper learning curve can be seen in the overall project durations—the San Marcos Lempas School took 80 days to complete, whereas the Zamoran School took just 41 days.

Concrete Slab

The basis of all RBS structures is a concrete slab. Monolithic slabs were used in El Salvador; however, nothing about the RBS restricts the use of floating slabs instead. A unit that can build a slab for a CMU structure can also build one for the RBS.

First, unless the plans have already taken expansion into account, slabs must be slightly oversized to account for the predictable expansion of the wall forms in hot environments. If the slab is not oversized, the walls may overhang the edges of the slab by as much as an inch at points. Oversizing ensures that the walls are completely supported by the slabs and creates a professional appearance.

Soldiers brace the wall of the Zamoran School.

Slab and rebar for the Lempas project

The vertical rebar that will weave through the vinyl wall forms may be placed in the slab while the concrete is still wet. However, if the concrete is allowed to set (and concrete sets quickly in hot climates), engineers will need to drill holes for the rebar instead. To do this, units must be prepared with powerful (preferably pneumatic) drills and have three bits for each drill. Examples of suitable drills are the pneumatic drills in the small emplacement excavator (SEE) truck BII or the Marine Corps compressor-driven drill sets. To reduce wear on the drill bits (which are difficult to replace while deployed), the site crew must ensure that the metal reinforcing mesh is either set back from the edges of the slab or fixed so that that these vertical holes will not strike the mesh or reinforcing bar.

Form Distortion

The RBS forms were initially designed for use in Canada. They begin expanding once the ambient temperature exceeds 5°C or 41°F. The manufacturer has studied this expansion and can complete building drawings with this expansion taken into account if you provide the expected ambient temperature at the time of the pour. However, if you are using a standard military design drawing that does not account for form expansion in heat, use the formulas below to project how much larger your forms will be when assembled in a certain heat. Note that the following formulas are for 6-inch/150-millimeter panels. Different formulas are available for 4-inch/100-millimeter and 8-inch /200-millimeter panels.

Δ = overall change in length

L = planned length of wall being considered

T = ambient temperature at the expected pour time

If you are measuring length in meters and temperature in Celsius, use the following formula to determine the change in length in your wall given the temperature:

$$\Delta_{millimeters}=(((T_{celsius}-5)/15))(L_{meters}))$$

If you are measuring length in feet and temperature in Fahrenheit, use this formula to predict your change in inches:

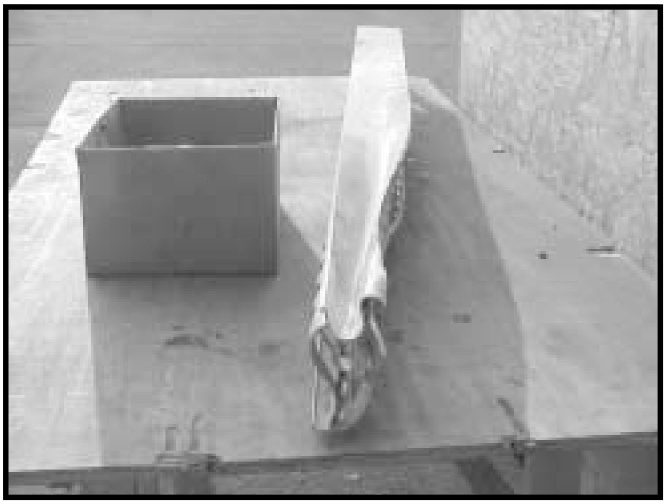
$$\Delta_{inches}=(((T_{farenheit}-41)/27)(L_{feet}/40)(.48))$$

If you are faced with an existing slab that was not poured with this expansion in mind, there are two adaptations that can help minimize form expansion and fit the walls to the slab. If the projected wall overhang is large, examine the plans to see if there are any RBS panels you can remove from the form structure to meet the slab size. If the projected overhang is small, tap the panels tightly together with rubber mallets during assembly. RBS staff engineers have stated that the form expansion is otherwise irreversible, so if the modifications above are not enough, you may need to accept and manage wall overhang on the slab.

Form expansion is not the only challenge heat brings to RBS construction. In temperatures higher than 30°C or 87°F, RBS panels begin to soften. Softened form walls become more susceptible to hydraulic pressure from fluid concrete and tend to bow outward when filled. In El Salvador, the high heat and fluid concrete combined to create schoolhouse walls with noticeable inward and outward bends and even form blowouts.

To minimize the distortion and control possible blowouts, first cool the forms with a light spray of water. Not only will this stiffen the forms slightly by cooling them, but it will also help the concrete fill the forms completely and minimize air pockets. After spraying, fill the forms in thinner lifts, using five or six lifts instead of the typical three. This reduces the amount of fluid concrete in the forms at any one time and thus the hydraulic pressure exerted on the softened forms. Third, combine these thinner lifts with increased wall bracing. In the heat of El Salvador, however, the bracing had to be tripled and augmented by additional braces within the structure to produce smooth, straight walls with a pleasing appearance.

Soldiers work on the school at Zamoran.



A heat-damaged RBS panel

Storage

During shipment and storage, strict handling requirements must be followed to prevent damage to RBS panels. Panels that are at the bottom of large stacks, or have additional equipment piled on top of them, become irreversibly warped, particularly in the heat. In most cases in El Salvador, engineers could still fit warped components into the formwork once pieces had softened in the sun, but these pieces cost a good deal of labor time and effort to force into place. In the worst cases, however, some panels were completely unusable.

When temperatures regularly exceed 30°C (87°F), the following steps are recommended to protect RBS components:

- Store vinyl components in the shade or cover with loose tarps that provide shade but still permit airflow.
- Do not store vinyl components in unvented containers, as these can become hot enough to melt RBS parts.
- Store all components in flat, straight piles with continuous support underneath. If components are stored without even and flat support, they will become permanently warped.
- Do not store other equipment on top of RBS panels. In temperatures over 30°C (87°F), do not stack RBS panels more than 1 meter (40 inches) high.

Quality Control

With CMU construction, progress on the walls is gradual, and leaders have time to identify problems and correct them as they occur. Individual blocks that are out of line are easily identified and can be adjusted, or even knocked out and replaced. With the RBS, once the concrete is poured into the forms and sets, nearly all the previous steps of construction become irreversible. Consequently, quality control of every detail before filling the walls with concrete is necessary. A full workday dedicated to quality control—including rechecking the formwork level and plumb, bracing tightness, and rebar connections—produces the best results.

BOM Management

With CMU construction, if blocks are lost or broken in storage, one simply obtains more blocks, since CMU blocks are virtually identical from block to block, vendor to vendor, and even country to country. But with the RBS, if you break or lose a component you're stuck, since the nearest replacements may be in storehouses in Ontario. In the worst cases, components may have been custom-made for your project and may need to be remanufactured.

Even if all the RBS parts are intact, it is easy to misuse them. Most parts can be connected easily to other parts, and many look very similar to each other. Without supervision, engineers may use wall sections without conduit where plans call for conduit, or even insert sections with very slightly different widths in the wrong locations in the walls, creating opposite walls of unequal lengths.

In operational terms, what this means is that RBS components must be carefully inventoried, stored, and accounted for throughout construction. Outside of North America, loss, destruction, or accidental misuse of components is irreversible in a practical time frame. Rather than being an "extra duty" assigned to an unlucky junior NCO you don't trust to swing a hammer, managing RBS components is a valuable mission that is best performed by an experienced BOM manager.

Concrete Pumping System

RBS construction depends on crews being able to fill the form from above with concrete. In North America, this is usually done with a well-regulated concrete pump operated by crews on scaffolding. If all else fails,

Using a concrete bucket to fill the panels

The pump detail uses the large-volume hose to fill the panels.

engineers with ladders and pails of concrete could fill the forms, but this would take a very long time. For efficiency's sake, every effort should be made to find a concrete pump, either to deploy with your unit or to be on hand at your destination.

In general, lower-volume pumps are preferable to higher-volume pumps when filling RBS forms. Higher-volume pumps tend to create thick lifts, which create more hydraulic pressure and distort the forms under hot operating conditions. Higher-volume pumps also have larger-diameter hoses that become extremely heavy when filled with concrete. In North America, with a well-regulated pump, contractors generally start and finish a pour with one crew.

In El Salvador, the only available concrete pump in the region was a large-volume pump used for quickly pouring industrial slabs. The "pouring crew" was a grueling six-man detail that had to be rotated every 20 minutes as soldiers grew tired from steering the heavy, bucking concrete hose into the narrow RBS wall panels. This large-volume hose had a wider diameter than the RBS panels, which allowed concrete to spray over the surfaces of outer walls, requiring additional cleanup before the concrete hardened.

Spillage resulting from using an oversize pump

An alternative to a missing or an inappropriate concrete pump was used in Nicaragua. Here, a basin of concrete was suspended with a crane over an RBS wall. By managing a chute from this basin, engineers could gravity-feed concrete into the forms. This was much less work for the engineers and used labor and concrete more efficiently. However, it required lowering and refilling the basin often and was somewhat slower.

Maximum filling efficiency with the RBS can only be obtained with a concrete pump with a hose or nozzle diameter smaller than the width of the RBS panel you are using. Other options are available, but these will absorb more manpower, equipment, and time.

Summary

The RBS is simple to use and creates concrete or reinforced-concrete walls superior to CMU walls. RBS construction has the potential to be dramatically faster than standard CMU construction. But to attain this speed, task forces need to be familiar with the RBS, be trained in their other construction tasks, manage RBS BOM carefully, adapt construction techniques to hot weather, and ensure that suitable concrete-delivery systems are available. Otherwise, the RBS will create sturdier buildings than with CMU construction, but it will not necessarily do so faster or more efficiently.

Captain Pickands, who is now attending the Engineer Captain's Career Course at Fort Leonard Wood, Missouri, was chief of projects at Joint Task Force–Bravo, Soto Cano Air Base, Honduras, when this article was written. Previously, he was the deputy secretary of the general staff and deputy division G5, 1st Infantry Division, and engineer operations officer for Joint Task Force–Kelly. CPT Pickands holds a bachelor's in political science from Cornell University and a master's in international training and education methods from American University.

For more information concerning New Horizons projects and planning, contact the USARSO DCSEN engineer planner, presently Major Humberto Ramirez (ramirezh @usarso.army.mil).

For more information on the Royal Building System and its applications, visit the company's Web site at www.rbsdirect.com.